Research Report 1270

LEVEL II

(13)

RECENT ARI RESEARCH ON THE DATA ENTRY PROCESS IN BATTLEFIELD AUTOMATED SYSTEMS

AD A109667

Irving N. Alderman, S.L. Ehrenreich,
and Richard Bindewald

HUMAN FACTORS TECHNICAL AREA

U. S. Army
Research Institute for the Behavioral and Social Sciences

September 1980

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER Research Report 1270	2. GOVT ACCESSION NO. AD-A109 667	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) RECENT ARI RESEARCH ON THE DATA ENTRY PROCESS IN BATTLEFIELD AUTOMATED SYSTEMS		5. TYPE OF REPORT & PERIOD COVERED --
		6. PERFORMING ORG. REPORT NUMBER --
7. AUTHOR(s) Irving N. Alderman, S. L. Ehrenreich, and Richard Bindewald		8. CONTRACT OR GRANT NUMBER(s) --
9. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. Army Research Institute for the Behavioral and Social Sciences 5001 Eisenhower Avenue, Alexandria, VA 22333		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 2Q162717A790
11. CONTROLLING OFFICE NAME AND ADDRESS U.S. Army Combined Arms Combat Development Activity (CACDA) Ft. Leavenworth, KS 66027		12. REPORT DATE September 1980
		13. NUMBER OF PAGES 42
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) --		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE --

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

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19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Military information systems
Man-computer interaction
Input procedures
Computer-assisted message input
Training

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This paper reviews ARI research designed to improve the data entry process. The first and second section of the paper describes the data entry process in general as well as in the context of a specific battlefield automated system, the Tactical Operating System (TOS). Because it was used as an exemplar of the data entry process, TOS played an important role in the development of improved data entry procedures. The third section of the paper reviews the findings and conclusions of the many ARI research projects

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concerned with data entry. Among the areas covered in ARI's research program are:

a. How to format and display data entry information.
b. What safeguards can be developed to reduce the number of operator errors made and/or accepted by the system.
c. What kinds of operator job aids can be developed to improve performance.
d. How to improve operator training.
e. How to make the system's message codes easier to use and more memorable.
f. How to improve the design of keyboards.

The fourth section of the paper reports on efforts to analyze the cause of operator errors. This section also discusses the development of a simulation of the data entry process. The simulation is intended to facilitate system design by permitting the inexpensive evaluation of alternate data entry procedures. The fifth section presents a general discussion of the problems that have been encountered by the ARI research program. Also included here is a discussion on how this program might be improved in the future. The final section of the paper summarizes the operational implications of ARI's research results.

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RECENT ARI RESEARCH ON THE DATA ENTRY PROCESS IN BATTLEFIELD AUTOMATED SYSTEMS

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Department of the Army

September 1980

Army Project Number
2Q162717A790

Military
Information Systems

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FOREWORD

The Human Factors Technical Area of the Army Research Institute (ARI) is concerned with the demands of increasingly complex battlefield systems that are used to acquire, transmit, process, disseminate, and utilize information. This increased complexity places greater demands upon the operator interacting with the machine system. Research in this area is focused on human performance problems related to interactions within command and control centers as well as on issues of systems development. Such research is concerned with software development, topographic products and procedures, tactical symbology, user-oriented systems, information management, staff operations and procedures, decision support, and sensor systems integration and utilization.

An issue of special concern within the area of user-oriented systems is the improvement of manual data input procedures, especially in battlefield automated systems. The main source of information for tactical data systems is manual data entry--a slow, difficult, and error-prone process. The capability of tactical data systems such as the Tactical Operating System (TOS) to support command staff actions with accurate, complete, and timely information is dependent on the performance of the person who must manually enter information into the system. ARI's research program on data entry has resulted in simplified message formats, improved reference codes, aids for on-line preparation and verification of message entries, improved training procedures, techniques for error analysis, and simulation techniques to aid in the design process. The present publication summarizes the research performed on the data entry process by ARI over the past decade. The rationale of ARI's approach to the problems, the findings, operational implications, and further research requirements are presented.

Research in user-oriented systems is conducted as an in-house effort augmented through contracts. This report resulted from an in-house research effort responsive to requirements of Army Project 2Q162717A790 and to special requirements of the U.S. Army Combined Arms Combat Development Activity, Fort Leavenworth, Kansas. Special requirements are contained in Human Resource Need 80-304, "Interactive Procedures for Data Inputting, Organization, Retrieval and Purge."

Joseph Zeidner

JOSEPH ZEIDNER
Technical Director

RECENT ARI RESEARCH ON THE DATA ENTRY PROCESS
IN BATTLEFIELD AUTOMATED SYSTEMS

BRIEF

Requirements:

To increase the efficiency and accuracy with which operators enter data into battlefield automated systems.

Procedure:

This paper reviews ARI research designed to improve the data entry process. The first and second sections of the paper describe the data entry process in general as well as in the context of a specific battlefield automated system, the Tactical Operating System (TOS). Because it was used as an exemplar of the data entry process, TOS played an important role in the development of improved data entry procedures. The third section of the paper reviews the findings and conclusions of the many ARI research projects concerned with data entry. Among the areas covered in ARI's research program are:

a. How to format and display data entry information.

b. What safeguards can be developed to reduce the number of operator errors made and/or accepted by the system.

c. What kinds of operator job aids can be developed to improve performance.

d. How to improve operator training.

e. How to make the system's message codes easier to use and more memorable.

f. How to improve the design of keyboards.

The fourth section of the paper reports on efforts to analyze the causes of operator errors. This section also discusses the development of a simulation of the data entry process. The simulation is intended to facilitate system design by permitting the inexpensive evaluation of alternative data entry procedures. The fifth section presents a general discussion of the problems that have been encountered by the ARI research program. Also included here is a discussion on how this program might be improved in the future. The final section of the paper summarizes the operational implications of ARI's research results.

Findings:

ARI research has contributed to the improvement of the data entry process in battlefield automated systems. Major findings and operational implications derived from the ARI program include:

a. The number of different formats used in data entry should be reduced through possible consolidation.

b. The transformation and input of the TOS message should be performed by a single operator and as a single operation.

c. Menu selection is the superior technique for data entry.

d. Message formats are best designated by the use of an all letter code as opposed to a mixed alpha-numeric code.

e. Flexibility and cost efficiency in the design of data entry systems can be achieved through improved computerized modeling.

f. Response-sensitive training is an effective method for reducing training time without sacrificing input accuracy.

g. The Alpha-dot keyboard has value as a data entry device for use by frontline observers on the battlefield.

h. Approximately 80% of all data entry errors are not detectable by computerized error detection routines.

Utilization and Findings:

This report brings together the principal results of ARI's research efforts in the area of data entry. It provides interested system proponents and developers with convenient access to recommendations and guidance for improving the data entry process in battlefield automated systems.

RECENT ARI RESEARCH ON THE DATA ENTRY PROCESS
IN BATTLEFIELD AUTOMATED SYSTEMS

CONTENTS

LIST OF TABLES

LIST OF FIGURES

RECENT ARI RESEARCH ON THE DATA ENTRY PROCESS
IN BATTLEFIELD AUTOMATED SYSTEMS

INTRODUCTION

The U.S. Army is engaged in the development of over 90 different tactical data systems which will improve the effectiveness and efficiency of information processing on the battlefield. By automating many of the clerical and manual processing tasks involved in tactical information processing, these new systems will ameliorate the burdensome, time consuming, and error prone chores related to the collection, processing, and presentation of information. These systems will provide field users with improved access to a more accurate and a more comprehensive data base of tactical information.

The data entry process is critical to the operation and maintenance of any battlefield automated system. Delays and errors that occur during data entry deprive system users of timely and accurate information. Battlefield automated systems can be no better than the quality of the data entered into them. When the data input process is degraded, the worth of the total system is compromised. Although elements of the data entry process will be automated, much of it will depend upon human performance. For the system to be successful, both the hardware and its human operators must be capable of operating in a combat environment where they are exposed to performance-degrading conditions.

This paper reviews ARI research designed to improve the data entry process. (An earlier presentation of this material was made by Alderman, 1976.) The next section of the paper describes the data entry process in general as well as in the context of a specific battlefield automated system, the Tactical Operating System (TOS). Because it was used as an example of the data entry process, TOS played an important role in the development of improved data entry procedures. The third section of the paper reviews the findings and conclusions of the many ARI research projects concerned with data entry. Among the areas covered in ARI's research program are:

- How to format and display data entry information.
- What safeguards can be developed to reduce the number of operator errors made and/or accepted by the system.
- What kinds of operator job aids can be developed to improve performance.
- How to improve operator training.
- How to make the system's message codes easier to use and more memorable.
- How to improve the design of keyboards.

The fourth section of the paper reports on efforts to analyze the causes of operator errors. This section also discusses the development of a simulation of the data entry process. The simulation is intended to facilitate system design by permitting the inexpensive evaluation of alternate data entry procedures. The fifth section presents a general discussion of the problems that have been

encountered by the ARI research program. Also included here is a discussion on how this program might be improved in the future. The final section of the paper summarizes the operational implications of ARI's research results.

THE DATA ENTRY PROCESS IN BATTLEFIELD AUTOMATED SYSTEMS

Outline of the Data Entry Process

Five critical operations must be performed during the course of a user-computer interaction (Ringel, Vicino, & Andrews, 1966). Figure 1 provides a graphic representation of these operations and of the information flow associated with them. Three of these five operations constitute the data entry process:

Screen incoming data for pertinence, credibility, impact, priority, and routing.

Transform the raw data for input into automated storage devices.

Input the transformed data into storage devices for subsequent computation and display.

The two remaining operations are assimilation of the displayed data and deciding on courses of action. These operations are not part of the data entry process per se and are therefore not discussed in this paper.

The data entry process begins with the reception of messages or data for inclusion in the data base. These messages can vary widely in terms of their relevance, content, form, and completeness. Therefore, the first step in the data entry process is to screen the incoming messages and exclude from data entry those that are irrelevant (see Figure 2). However, most experiments and training exercises employ only relevant messages in their scenarios. Ambiguous data, erroneous data, deceitful data, and data out of context are not included. Thus, the screening operation tends to receive little attention during most test and design stages. Although the screening operation determines the content of the data base and may delay the relaying of messages, research emphasis has typically been placed on the transform operation.

The transform operation involves the selection of the appropriate format for translating the message data from free text into a style acceptable for data entry. Restrictions on the size of the data base often necessitate the use of abbreviations, codes, and other representations. A number of formats are available for the transformation of incoming messages. Each format is tailored to a different type of message as well as to the data base operation to be performed. Worksheets are usually used by operators to assist them in performing the transformation task.

The input operation involves the physical process of using an input device to transcribe data from messages or worksheets into the computer. Most systems provide a standard keyboard for entry of the message as well as a cathode ray tube (CRT) for immediate display of the entered message. Operators verify the correctness of the transcribed message against the worksheet prior to entering it into the data base.

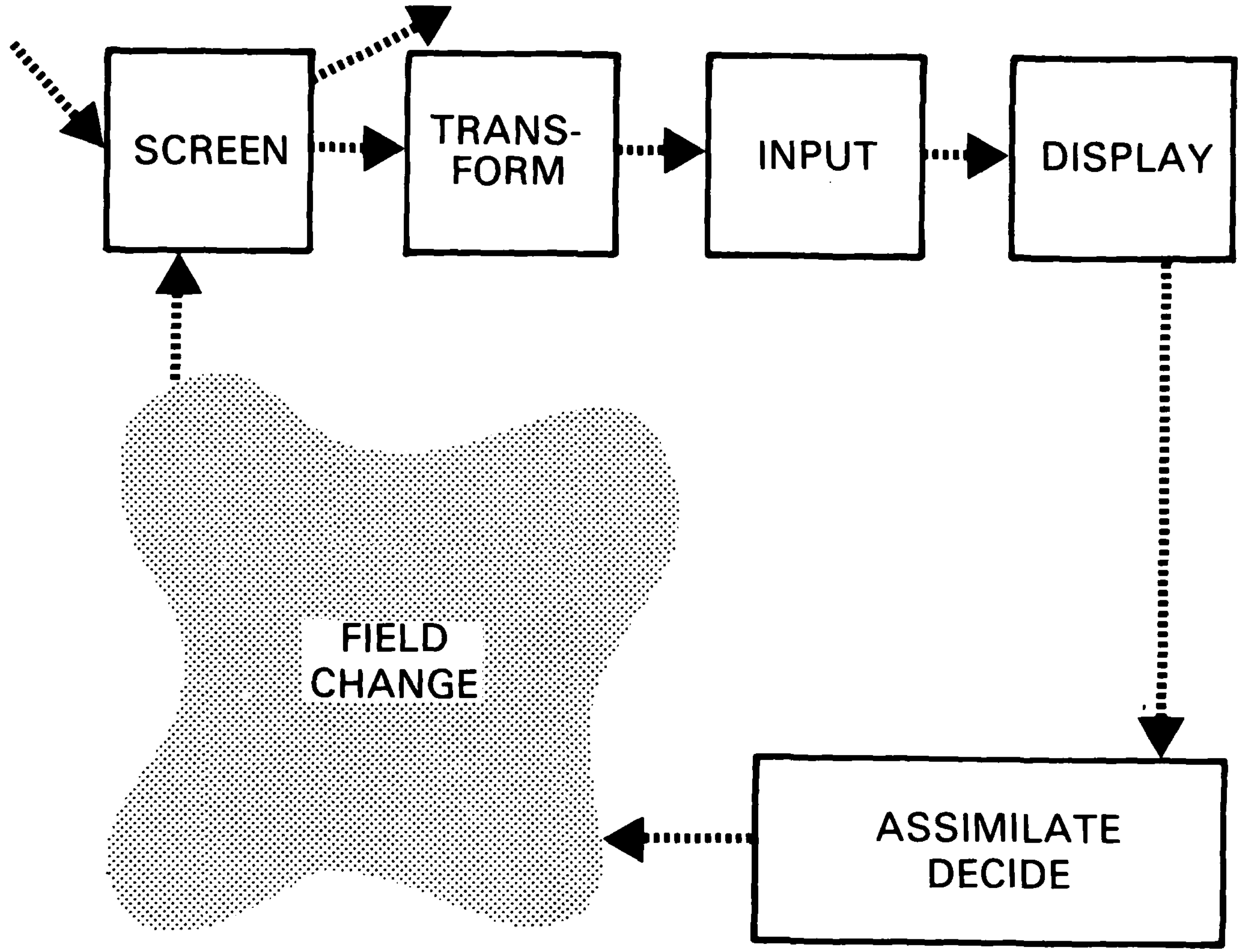

Figure 1. Schematic representation of operations and information flow in an automated TOS. (Ringel, Vicino, & Andrews, 1966)

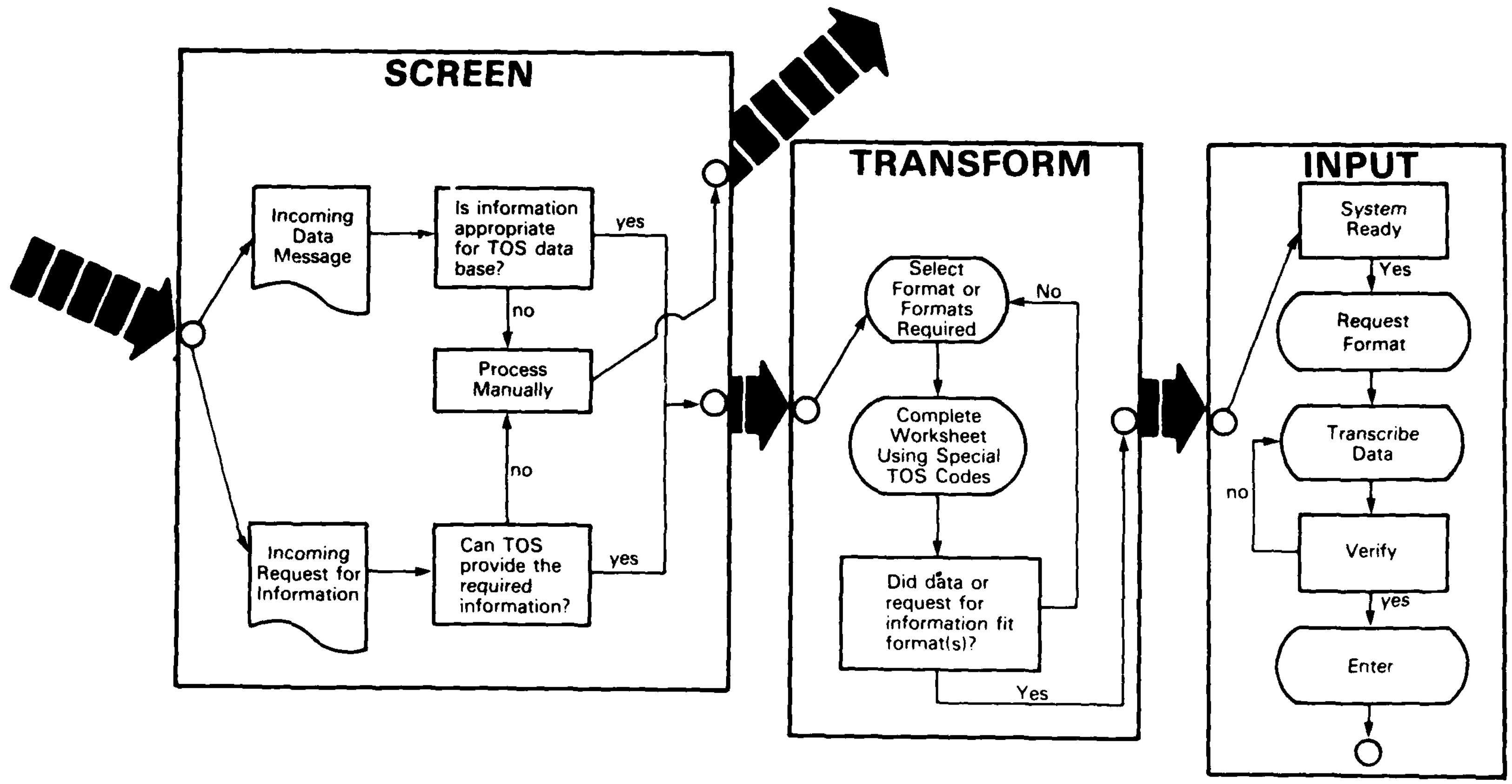

Figure 2. Schematic representation of the screen, transform and input operations and data flow in the Seventh Army automated TOS. (Adapted from Baker et al., 1969)

TOS

TOS was a battlefield automated system designed to provide command staffs with a computerized method for the storage and retrieval of battlefield information. The development of TOS in a user setting was begun in 1965 and resulted in a Seventh Army TOS (SATOS), designed from commercial equipment, being introduced into the field for testing. Upon completion of testing in about 1969, Headquarters, Modern Army Selected System Test, Evaluation and Review (MASSTER) relocated the experimental TOS to Fort Hood, Texas, in order to support the Developmental TOS (DEVTOS) activity. This in turn led to an effort to develop a division level system known as the TOS Operable Segment (TOS^2). In 1980, development of a second generation command support system, SIGMA, was initiated. (For further discussion of the early history of TOS, see Baker, 1972a.)

The TOS configuration (circa 1970) is shown in Figure 3. TOS consisted of the following functional groups:

- User Input/Output Device (UIOD)--enables remote users to communicate with the system and other users; consists of a television type cathode ray tube (CRT) display with an associated keyboard and a typewriter printer.

- Remote Station Data Terminal (RSDT)--an intermediate message processor/transmitter between UIODs and the Central Computing Center.

- Central Computing Center (CCC)--stores the TOS data base, performs TOS computations and data manipulations, and processes all messages to and from the RSDTs.

Data entry in the experimental TOS begins with an incoming message being received from a remote unit. This message, usually in the form of free text, is then translated into the TOS message format by an action officer. In performing this task, the action officer is guided by TOS message worksheets. Next, an operator transcribes the message from the worksheet to the UIOD. After the transcribed data is verified against the worksheet, the operator transmits it to the CCC. The input data is then edited and verified by the CCC. If any errors are detected by the CCC, an error message is sent to the operator. When this occurs, the operator corrects the error and reenters the data into the systems. When the data is finally accepted, the CCC updates the data base.

The messages processed by the action officer can be categorized as either operational or relay. Relay messages are free text messages from one user to another and require only retransmission; thus they do not affect the data base. Operational messages are messages which modify the data base or which require a system response. They are of the following types:

- Data messages--serve to enter data into the system data base and to add, change, or delete previously entered data.

- Query messages--used to search the data base for specific information which is then output on the typewriter printer.

- Special Process Request (SPR)--used to perform calculations, summaries, and other manipulations of the stored data.

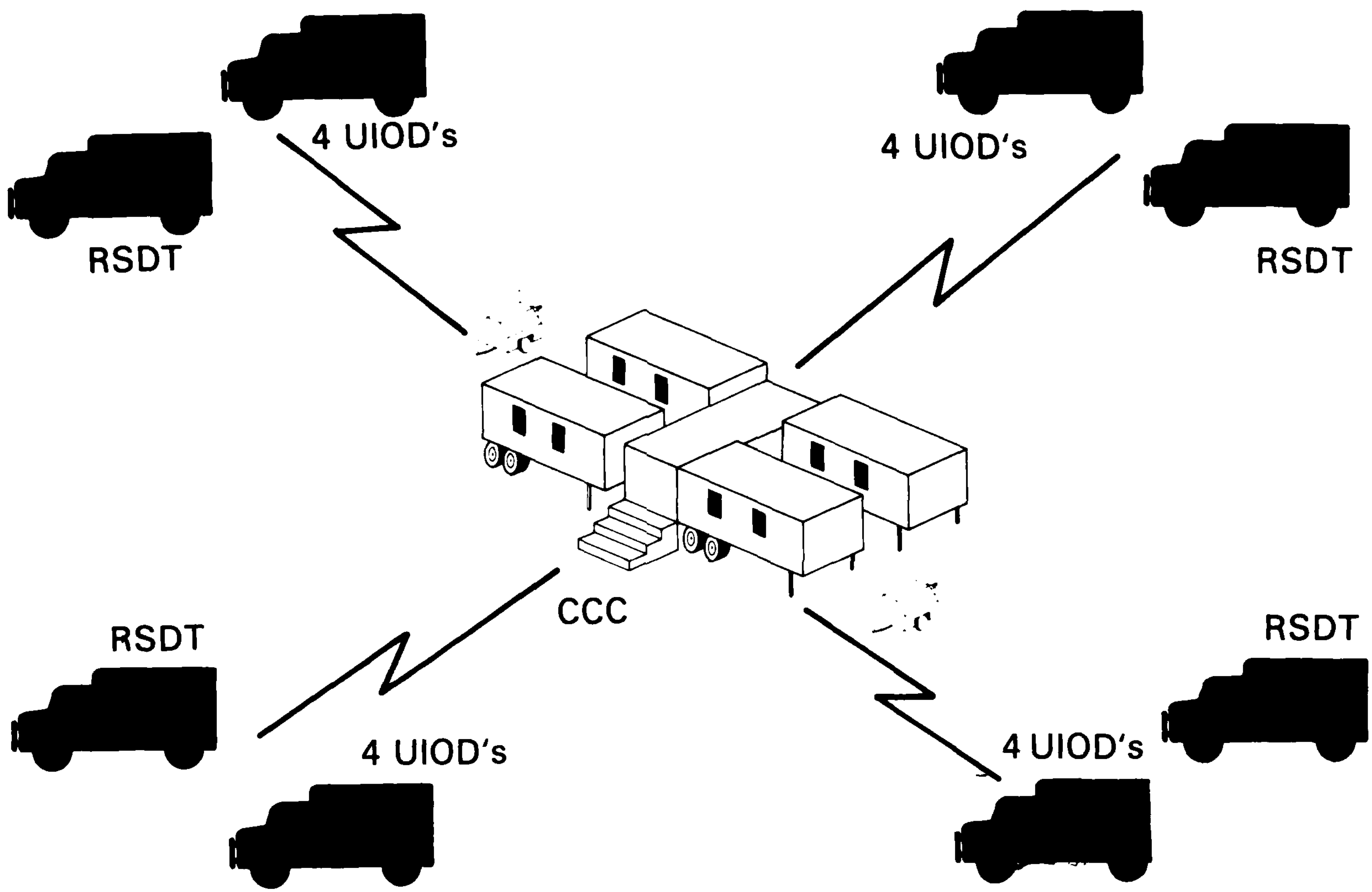

Figure 3. Configuration for first increment of transportable hardware for the Seventh Army TOS. (Baker, 1972)

• Standing Request for Information (SRI)--serves to establish automated and immediate dissemination of pre-specified information to designated UIODS.

Entry of these operational messages requires the completion of highly structured worksheets. A large number of different worksheets are required to accommodate all possible combinations of message types and functional areas. Operational messages may require more than one worksheet to enter all the relevant data in an incoming message (see Baker, 1972a).

Many of the early data entry studies performed by ARI used the TOS design as an exemplar of battlefield automated systems. By so doing, these early experiments were made more realistic and their results were directly usable by both TOS and other prospective systems.

RESEARCH REVIEW

Research on data entry has revolved around the transform and the input operations. In most instances, these operations were studied together and therefore they are discussed together below. In seeking to improve the data entry process, research efforts centered on the following features: message format selection, on-line versus off-line transformation of free text, verification by the operator of the input stage, job aids for the operator, training procedures, typing aids and new keyboard designs. A summary of this program is provided in Table 1.

• Format Selection is a critical part of the transform process during data entry. For the experimental TOS, users are required to select the correct format(s) (for transforming a message) from about 500 choices. In the majority of cases, the transformation of a single English text message will require the use of more than one format (Baker, 1972a). A sample format is shown in Figure 4. Baker, Mace and McKendry (1969) investigated how to improve performance during format selection. In their experiment, operators were assigned to one or two format selection procedures. One group used a menu type listing of available TOS formats. The second group used a simple job aid which provided the same information but in the form of a table of reference codes. Data entry was performed manually (i.e., handwritten). The two groups of operators showed no significant differences in their performance. Their error rate for selecting the proper format was 22%, suggesting that approximately one message in five would be incorrectly entered in a real life situation. Error rates differed as a function of message type and subject matter. The most common error made involved data being sent through TOS as a relay message when, in fact, the data should have been entered as an operational message. This type of error deprives the command center of important information. The mean time for data entry was observed to be 50 seconds. This included the time required to read the message, select a format and then transform the message. As a result of their findings, Baker et al. hypothesized that the error rate in an operational system is compounded by the large number of successive operations being performed. They suggested that the action officer, who manually prepares the message worksheet and then passes it to the operator for input, is both redundant and a source of error. In addition, they recommend that the number of different formats used by the TOS be reduced and that operator training on correct choice of a format be improved.

Table 1

ARI Laboratory Experiments on Data Entry

Study	Task	Results	Conclusions
Baker, Mace & McKendry (1969) TRN 212	To select the appropriate format for a TOS message. Experimental conditions compared: the use of a menu vs the use of a special job aid (i.e., a table of references).	There was no difference between the two selection procedures. The error rate was 22%.	Need to clarify method for selecting the correct format; need to reduce (through consolidation) the number of formats used by the system; noted the needless redundancy in the action officer's and operator's task.
Strub (1971) TRN 226	To translate and input messages into a TOS. Experimental conditions compared: (1) on-line vs off-line translation; (2) verified vs unverified input.	On-line translation reduces error rates; verification reduces error rates but at a cost in time.	Messages should be input directly onto the CRT without the use of paper formats as an intermediary step.
Strub (1975) TP 262	To translate and input messages into a TOS. Experimental conditions compared: (1) a computer-assisted inputting aid vs a checklist in handbook form; (2) CRT display of selective sections of the format vs CRT display of the complete format. A fifth control condition did not display the format on the CRT.	There were no significant differences among the experimental conditions but all were superior to the control condition. The edit routine failed to detect 80% of the user's errors.	CRT display of the input format contributes to superior performance.

(Continued)

Table 1 (Continued)

Study	Task	Results	Conclusions
Gade, Fields & Alderman (1978) TP 349	Subjects were trained on TOS data entry procedures. The training conditions varied with regard to the sophistication of the error feedback messages: no feedback, minimum feedback, edit feedback, remedial feedback, response-sensitive feedback.	Response-sensitive feedback training (where the training session automatically adjusts to changes in subject performance) was the superior training technique.	A response-sensitive training strategy should be implemented if it is found to be cost effective.
Fields, Maisano & Marshall (1978) TP 327	To enter messages into a TOS. There were four input methods: straight typing; typing with error-corrector; menus; typing with autocompletion and an English option.	The use of menus was the most accurate input method. The four input methods did not differ in speed.	Menus are recommended for use in inputting tactical data.
Nystrom & Gividen (1978) TP 326	To learn one of two TOS message reference codes. One set of codes consisted of two letters and one number (LL#); the other code consisted of four letters (LLLL).	The LLLL code was learned faster and more accurately.	The LLLL code should be used in future designs.

(Continued)

Table 1 (Continued)

Study	Task	Results	Conclusions
Sidorsky (1974) TP 249; (1979) WP 79-07	To test a new keyboard (the 5-key Alpha-dot keyboard) for the inputting of TOS messages.	Data entry was as fast with the Alpha-dot keyboard as with the standard keyboard under certain conditions.	Alpha-dot has the potential of increasing the speed, accuracy and flexibility for inputting data in battlefield situations.

TRN = ARI Technical Research Note.

TP = ARI Technical Paper.

WP = ARI Working Paper.

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ORIGIN ! / ; SCTY ! / ;

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/R-O/A-N, TANKS / / ; /R-O/PCT-OF-TOE, TANKS-PCT / / ;

/R-O/A-N, WHEEL-VEH / / ; /R-O/PCT-OF-TOE, WH-VEH-PCT / / ;

/R-O/A-N, TRACK-VEH / / ; /R-O/PCT-OF-TOE; TR-VEH-PCT / / ;

/R-O/A-N, ARTY / / ; /R-O/PCT-OF-TOE, ARTY-PCT / / ;

/R-O/A-N, MISSILES / / ; /R-O/PCT-OF-TOE, MSL-PCT / / ;

/R-O/A-N, ACFT / / ; /R-O/PCT-OF-TOE; ACFT-PCT / / ;

/R-O/A-N CBT-EFFECT / / ;

/ID OR SWBD-DSGTR, UNIT / ;

/R-O/ECHELON, ECHELON / / ; /UNIT-TYPE TYPE / ;

BRANCH / ; CATEGORY / ; NATION / ;

/ASGD OR ATCHD/ARTY-MISSION, SUBOR-TYPE / / ;

SUBOR-TO / ;

TIME FRAME / FROM / / TO / ;

/DATA MSG ORIGINATOR, ENTERED-BY / ; /R-O/SCTY-LEVEL; CLASSIFIED / / ;

Figure 4. Sample unit status query worksheet. (Baker et al., 1969)

• <u>The Redundancy of the Action Officer's and the Operator's Tasks</u>, as defined by Baker et al. (1969), was investigated by Strub (1971). In an experiment designed to explore alternative means for improving the entry process, two modes of format preparation (on-line and off-line) were compared under two levels of verification (with and without). On-line entry used the terminal for preparation (see Figure 5); off-line entry required the preparation of a paper format prior to data entry into the terminal. In the verified condition, two operators compared their completed formats, resolved any discrepancies between the two, and entered the formats individually. The unverified condition omitted these steps, i.e., the operator performed the input operation without an error check. A fifth group of operators served as a control. These operators prepared formats using procedures similar to those employed in the experimental TOS, i.e., formats were prepared on paper by one operator and transcribed onto the terminal by another operator. (In the prior conditions, both the preparation and entry were performed by a single operator.) Significantly fewer errors were obtained in the on-line preparation (11.[illegible]) than in the off-line preparation (14.8%). There were no reliable differences between these two conditions in speed of input. Use of the verification procedure reduced errors approximately one-third (15.7% vs 10.3%) but required approximately one-third more time (4.98 vs 6.81 min). Both procedures were superior to the inputting process used in the experimental TOS. From these findings, Strub recommended on-line inputting to reduce errors and noted that although the verification procedure reduced errors, the trade-off in time and manpower must be considered.

Figure 5. "Action Officer" subject completing format on CRT. (Strub, 1971)

• Aids to Assist in Message Formatting were evaluated in an experiment by Strub (1975). Both of the aids that were studied provided the user with data entry information, instructions, and examples of legal entries. One aid was computer-assisted and presented this information on the CRT. The other aid was a checklist for formatting free-text information into computer acceptable terminology. This aid was in the form of a handbook. A second variable that was investigated involved the completeness of the data entry format shown to the subject. In one condition, the subject indicated which subsection of the format was to be displayed on the screen. In the other condition, the entire format, including irrelevant sections, was displayed to the subject. In both cases, the subject was required to insert the appropriate data into the blank spaces within the format. A fifth condition served as a control. In this condition, the subject used the reference handbook but wrote the input message without the aid of a CRT display format. The experiment found that the time required to perform the data entry task did not differ significantly among the four experimental conditions but the fifth (control) condition did take an average of 4.6 minutes longer per message. No significant differences in accuracy appeared. An analysis of the input errors was performed to evaluate the effectiveness of the error detection routine. The analysis revealed that 80% of the input errors went undetected. Also, "friendly" messages were completed with greater accuracy and speed than "enemy" messages, perhaps because they may have been simpler to format.

Strub recommended that error analyses be performed to determine the ratio of detectable to undetectable errors. This would provide a valuable estimate of the frequency of undetected errors in the real world. Strub also suggested that the TOS formats might be simplified. Research performed in conjunction with Project MASSTER (which was to later become an element of the Training and Doctrine Command) indicated that the consolidation of formats could result in a savings of 49 seconds in the time required to enter a message (Strub, 1975). Error rates for the consolidated formats were not reported.

• Improved Training represents another approach to improved operator performance. Software/courseware training modules can be embedded within operating system both to train operators and to maintain a high level of proficiency once trained. The effectiveness of embedded training programs depends on the development of optimized training strategies which are responsive to the student's history, current skill level, etc., and satisfy the necessary conditions for learning (e.g., feedback of errors). An experiment by Gade, Fields and Alderman (1978) compared the effects of selective feedback on performance during training and simulated operations. Five conditions were defined by the type of computer feedback provided to the student when an error occurs. The five types of feedback were:

1. No Feedback.

2. Minimum Feedback--error message only.

3. Edit Feedback--error message, correction required.

4. Remedial Feedback--error message, correction required, correct entry.

5. Response Sensitive Feedback--error message, correction required, correct entry, automatic entry.

The error message informs the student that the last entry was in error; correction required indicates that erroneous entries must be corrected before proceeding; correct entry provides the student with both the erroneous entry and what the entry should have been; for automatic entry, the computer maintains a record of the subject's performance and stops testing those entries which have been mastered to criteria. After training, the subjects were given a performance test. In comparison to the other conditions, Response-Sensitive feedback was found to be most effective in reducing training time. However, it was no different in its effect on accuracy. Of the errors made during testing, over 90% could not be detected by the system's edit routines.

Gade et al. recommended that any proposed use of the above training techniques should take into consideration the trade-off between reduced training time and increased cost of training development. Also, the development of more effective error detecting routines was recommended, although this is not likely to produce a complete solution. Other possible means for reducing error rates are to improve formats and to better define legal entries. Based upon the above experimental results, it does not appear that improved training will eliminate the number of errors that go undetected by the present system.

- Typing Aids were investigated by Fields, Maisano, and Marshall (1978) in an extension of earlier work developing computer aids for message input. The authors systematically assessed four methods of inputting TOS messages concerning enemy activity. The four inputting methods were: (1) typing--the user types the appropriate code into a message format; (2) typing with an error corrector--the computer automatically attempts to correct common spelling and/or typing errors; (3) menus--from a list of options, the user indicates which entry is desired; and (4) typing with autocorrection and an English option--the user could choose to type either the word or its abbreviation (i.e., English option) or the user could choose to only type enough characters from either the word or its abbreviation for the computer to uniquely identify it (i.e., autocompletion)

The menu method of data entry produced 40% fewer errors than the typing only method. The error corrector also decreased the number of errors by 11%. However, autocompletion with an English option resulted in an increase in the error rate as compared to the typing only method. (Although autocompletion was utilized heavily by the subjects, the English option was not. Instead, subjects showed a strong preference for using abbreviations in conjunction with autocompletion and rarely did they use the other options.) Autocompletion should therefore not be used unless specific operational needs warrant it. It also might prove to be more effective with operators experienced in its use. For users with limited (one day) experience, there were no significant differences in speed among the four methods. The menu method required a slightly (although not significantly) longer data entry time. This may have resulted from a lag in the time required to display successive menus on the CRT.

- The Memorability of Codes is a problem for most systems. Early versions of the experimental TOS used reference codes consisting of two letters and one number (LL#). The two letters were used to indicate message format (e.g., enemy unit status, standing request for information file) and the number was used to indicate action code (e.g., add, delete). An alternative set of codes based on four letters (LLLL), usually an acronym of the message format and the action code, was recommended. A sample of the two coding techniques is shown in Table 2. A code is formed by joining a message title code to an action

Table 2

Old (LL#) and New (LLLL) Message Format Codes
Used in the Experimental TOS
(Nystrom and Gividen, 1978)

Message Titles with Old (LL#) and New (LLLL) Codes

G2 message titles	Message title code Old	New
Enemy unit status	EA	EUS
Enemy situation data	EC	ESD
(Enemy) intelligence summary	ED	EIN
(Enemy) intelligence working file	EE	EWF
Enemy situation data base index	EG	EDX
Relay[a]	AA	REL
Named area of interest	AA	NAI
Standing request for information file	AA	SRI

Action Names with Old and New Codes

Action name	Action code Old[a]	New
Add	1	A
Change	2	C
Delete	3	D
Query	4	Q
Special processing	5	P
Establish standing request for information	6	S

[a]Plus these special cases:

1. Use an action code of 0 to add a Relay message.
2. Use an action code of 8 to delete an "SRI File" message.
3. Use an action code of 9 to query the "SRI File."

code (e.g., EA2, EUSA). Nystrom and Gividen (1978) compared the relative ease of learning the two sets of message format-action codes. Comparison of the error rates showed a reliable difference in learning the codes, i.e., the error rate for learning the LLLL codes was less than half that for learning the LL# codes (13% vs 29% errors for enlisted men, 11% vs 21% for officers working on one sample list, and 7% vs 15% for officers working on another sample list). In addition, the time required to meet a learning criteria for the LLLL groups was approximately 60% of the time required for the LL# groups. Thus, the LLLL code was learned in less time and with fewer errors than the LL# code. A detailed analysis of the error rates suggested several revisions in the LLLL code that have the potential of reducing the error rate to 5% or less.

- Improved Keyboard Designs were studied by Sidorsky (1974) in research designed to evaluate the impact of a nonstandard keyboard on the data entry process. Sidorsky specifically compared data entry using his own "Alpha-dot" five-key keyboard versus a CRT with a standard keyboard. The Alpha-dot system is one in which the keys to be pressed are determined by the shape of the alphanumeric character being entered. The set of keys that most closely resembles the character is pressed. The Alpha-dot code and two Alpha-dot entry devices are shown in Figure 6. With less than 5 hours of practice, trainees using the Alpha-dot tablet were able to enter free messages at 60% of their standard keyboard rate. Perhaps more significant was the finding that formatted (TOS type) messages were transmitted at a rate equal to or exceeding that of the standard keyboard. Subsequent studies have similarly demonstrated the feasibility of the Alpha-dot keyboard. Sidorsky (1979) showed that enlisted personnel were able to effectively master the system with 1 to 3 hours of practice. Similarly, Gopher and Eilam (1979) taught the Alpha-code (in Hebrew) to fighter pilots who mastered it quickly and went on to successfully operate it during a simulated flight mission.

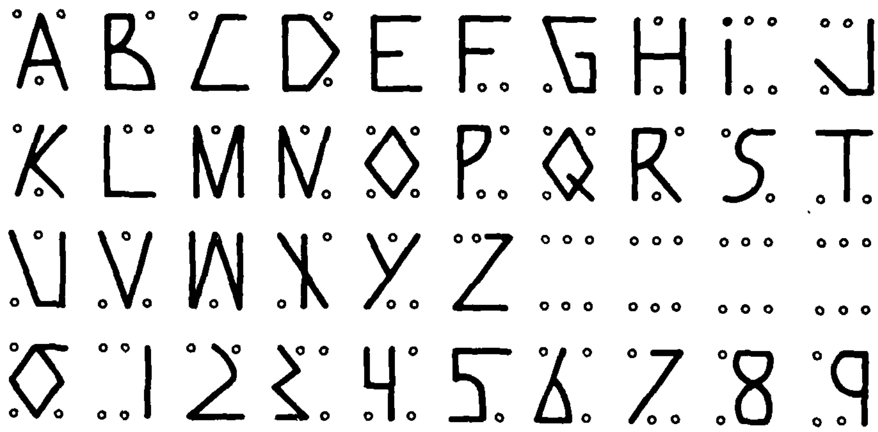
ANALYSIS OF THE DATA ENTRY PROCESS

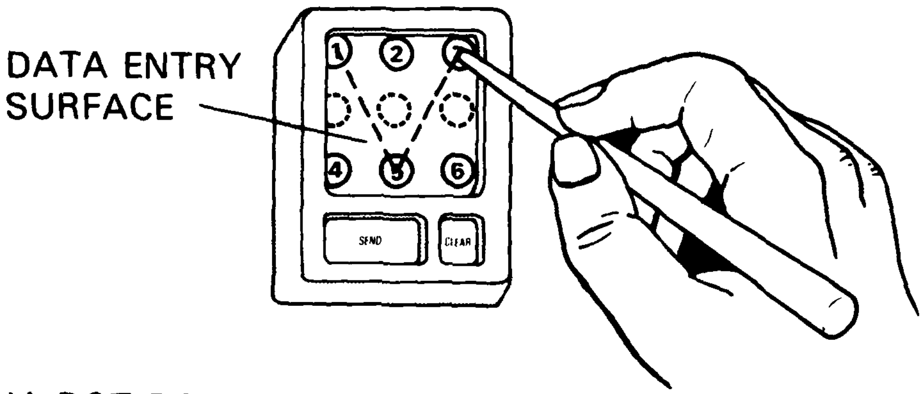
In addition to both field evaluations and laboratory experiments, a number of analytical efforts have been performed in the area of data entry. These efforts have produced practical tools for aiding in the design of data entry procedures. Two of these efforts have provided the analytic tools necessary for discovering and evaluating error prevention techniques. The other efforts created a quantitative model of the data entry process. This model can be used to inexpensively simulate, and thus evaluate, alternative designs for the data entry process in the TOS.

Error Analysis

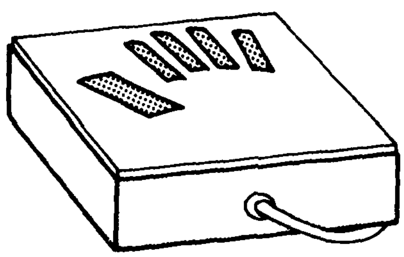
Nawrocki, Strub, and Cecil (1973) developed an error analysis technique based on comparing the entered messages with perfectly accurate messages. Any mismatches or discrepancies between corresponding entries were defined as errors. The errors were then categorized according to the type of failure that occurred in the inputting process (e.g., omission, commission). This technique for error analyses was first applied to the data obtained in two experiments performed by Strub (1971, 1975). Examination of these data revealed that three error categories--omission of an appropriate entry, commission of an inappropriate entry, and glossary (i.e., "selecting an inappropriate entry from among

ALPHA-DOT TABLET CODE





ALPHA-DOT DATA ENTRY DEVICE-TABLET TYPE
ENTERING THE LETTER "V"



ALPHA-DOT KEYBOARD

Figure 6. The Alpha-dot code and two types of entry devices. (Sidorsky, 1974, 1979)

a glossary of potential entries available to the operator")--accounted for about 80% of the errors. Yet these three categories represent errors which cannot be detected by computer edit-and-validate routines. Also, error rates were found to vary as a function of the type of message being processed. "Enemy activity messages produce a higher error rate than friendly messages and the bulk of this difference is in the category of omissions." The need to reduce this high, undetectable error rate has provided the impetus for work on identifying both the sources of errors and how errors can be countered.

The prevention and remediation of input errors was approached by Mace, Harrison, and Sequin (1979). Through the creation of a taxonomy, these authors sought to identify ways which input errors are made as well as ways by which they can be prevented. The report consists of four basic components: a scheme for error classification, a determination of the constraints imposed upon error remediation, an investigation of the design changes which might result in a reduction of errors, and a methodology for assessing the cost-effectiveness of alternative remedial actions. Each of these components are discussed later. A sample analysis is shown in Table 3. Mace et al. categorize input errors according to a number of dichotomous variables. For example, an input error can be one of either omission or commission; it can either be caught by the internal edit program or it cannot; it can involve either a quantitative or a verbal statement. By first explicitly identifying the nature of input errors, the authors can go to discuss means by which their numbers can be reduced.

Before viable remedial steps are devised, the system constraints must be determined. All corrective actions are not necessarily feasible. The task and design of the system place limits on what changes can be made. Two facets of system constraint are considered: (a) external influences such as the unit's size and weight limitations; mobility; temperature, dust, and humidity; supportability, reliability, and maintainability, and (b) internal influences concerned with distinctly human factors (e.g., operator ability, training, and experience).

Having determined the types of errors and the system constraints, alternative means by which to reduce the number of errors can be considered. Possible design changes are revised formats, improved abbreviations, changes in the input language, display of the default values, etc. Mace et al. caution against overzealousness in instituting a change for the purposes of eliminating errors. "Elaborate error prevention and detection procedures may have a negative impact on system responsiveness which may in turn negatively impact on user acceptance and the production of errors from boredom or lack of confidence with the system."

Having settled on a possible preventive or remedial action, a system designer must analyze the prospective costs and benefits involved in its implementation. Mace et al. provides a step-by-step description on how to perform this analysis using Multi-Attribute Utility Measurement (MAUM). The end product of the procedure is a utility value. In deciding between a number of alternative corrective actions, the system designer will choose the one which results in the largest utility value.

Table 3

Error Types, Causes, and Alternatives for Prevention and Detection
(Mace et al., 1979)

Error type	Cause of error	Prevention and detection
Omission of message set	Lack of knowledge of user/operator	User/operator selection
	Incompatibility between source document and input dialogue	User/operator training
	Misplaced document	Revise procedures--horizontal distribution of input activities
	Operator failure	Revise source document formats
		Revise input formats
Omission of data element group	Incompatibility between source document and input dialogue	Revise procedures--vertical distribution of input activities
	Skip a line or lose a page	Revise source document formats
		Revise input formats

(Continued)

Table 3 (Continued)

Error type	Cause of error	Prevention and detection
Ommission of data element	Improper presumption of default values	Use formats with explicit labels
		Display default values
	Element input into wrong location	Conditional error checking
	Loss of place in source or preformatted document	Conditional formatting
	Loss of place in dialogue with system, e.g., cursor position	Interactive dialogue
Valid codes/restricted items		
Verbal errors (Glossary)	Incorrect recall	Input language
	Incorrect recognition	Expanded definitions
	Transcription errors	Conditional, probabilistic, or adaptive error checking
Quantitative Errors	Incorrect scale conversions	Editing process
	Data input with incorrect scale	Formatting
	Incorrect rounding of numbers	Conditional, probabilistic, or adaptive error checking
	Careless transcription, including character transposition and decimal placement	

Simulation

The development and testing of a new system is an expensive endeavor. In order to reduce the costs involved in evaluating alternative designs and procedures, MANMODEL, a computer simulation of the data entry process was developed with ARI support. MANMODEL focuses on system tasks and procedures in an effort to estimate performance as it pertains to data entry. By varying input parameters, MANMODEL permits system designers to explore the effects on the data entry process of changes in manning levels, training, personnel selection and other factors. Thus, MANMODEL helps identify problem areas and provides a technique for evaluating potential solutions in a simulated context.

MANMODEL is based upon a qualitative model of system performance developed by Baker (1972b, 1976) and Baker and Ringel (1968).

> The model has been developed along three basic dimensions which are reflected in Figure 7. The first, that of data flow and the processing it requires, constitutes one dimension of importance. Hence, it is critical to "flow chart" the sequence of events or operations that constitute the logic of the system under examination. . . .
>
> For the second dimension, Task Analysis, each event in the data flow sequence is examined with respect to the task-equipment interactions that constitute that portion of the operator's job. . . . Essentially, a task analysis consists of the enumeration of the discriminations, decisions, and action responses which are necessary and sufficient to operate each component of the system.
>
> The third dimension refers to outside sources of variation which are normally considered external to the man-computer system, for example, the impact on system performance when level of training is varied. . . . (Baker, 1976, pp. 7-8).

A MANMODEL run begins with the generation of a queue of incoming messages. Through a stochastic process, the speed and accuracy with which these messages are processed is simulated. Along the way, numerous variables relating to operator performance (e.g., stress, fatigue) are calculated. (A sample listing of both the input and output variable used by MANMODEL are shown in Table 4.) At various points in the simulation, output reports are available to describe the status of the data entry process. These reports include such information as to how backed up the message queue is, what percentage of the time the operators are busy, etc., (see Table 4). A small sample of the simulated data that is generated by MANMODEL is shown in Figure 8. The simulated data shows the number of messages that have been received, backlogged and either completed, rejected, or interrupted by two types of data entry personnel (G3 action officers and IOD operators). Further insight into MANMODEL can be gained by inspection of the sensitivity tests performed on it. Figure 9 shows the predicted relationship between type of operator, level of operator skill and mean number of messages which are completed as opposed to messages that are carried over from one shift to another. A complete description of how MANMODEL operates and the data that it produces can be found in the following documents: Siegel, Wolf, and Leahy (1977); Siegel, Wolf, Leahy, and Bearde (1977); Leahy, Lautman, Bearde, and Siegel (1977); and Leahy, Siegel, and Wolf (1979a, b).

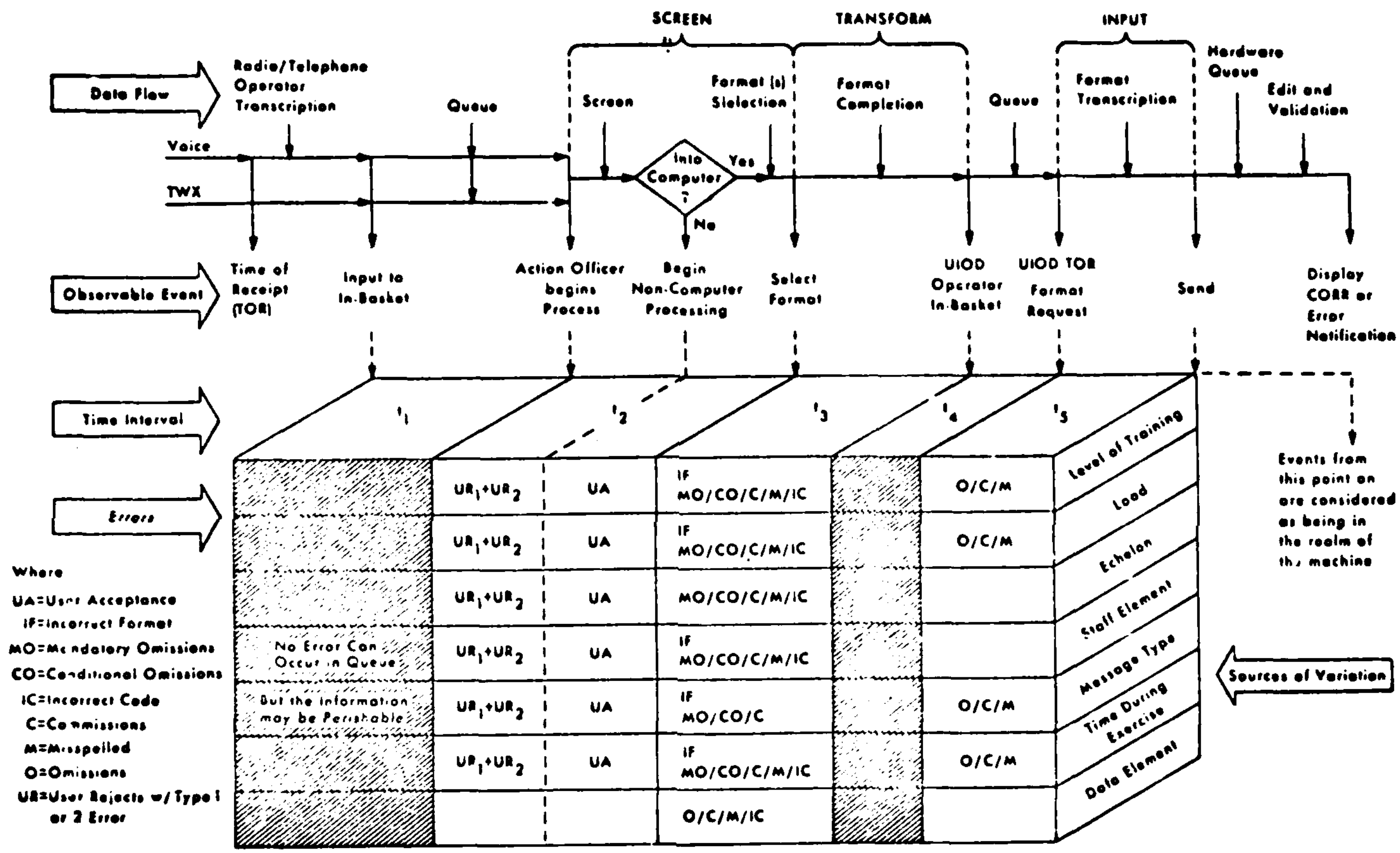


Figure 7. Representation of the model upon which MANMODEL is based. The three basic dimensions are: data flow, task analysis, and sources of variation. (Baker, 1972b)

Table 4

Sample Input Parameters and Output Options
Available with MANMODEL

Input parameters	Output options
Simulation: Run title, number of iterations, output print options.	Effectiveness Run Summary: Thoroughness, responsiveness, completeness, and accuracy with overall efficiency for each hour.
Systems: Personnel per duty position, shift duration, correlation and relative weights of effectiveness components, etc.	Manpower Utilization: Proportion of hour worked, messages processed and mean time, final stress and aspiration, and overall mean for each hour.
Function/Tasks: Tasks/duty level, criticality, segment delimiters, branching, performance time and errors, etc.	Workload Summary: Message backlog and messages delivered, completed, rejected, and interrupted by personnel type for each hour.
Personnel Characteristics: Speed, precision, stress threshold, level of aspiration.	Time Segment Summary: Time and proportion of total for each segment, message type and priority over each hour.
Message Characteristics: Number of messages, message length, frequency by type and priority, error rate by type, etc.	Error Message Processing: Mean time spent responding to and processing error messages by each personnel type.
Error Message: Vocalic center groups, search options, random walk, etc.	Error Run Summary: Number of error returns, information loss and number of message units for each hour and message type.
Interruption/Transmission: Time, hour, frequency, etc.	
Computer System Characteristics: System delay time/queue, number of entries, etc.	

DETAIL PRINTOUT FOR INSPECTION 3-19-72 APS

WORKLOAD SUMMARY

HOUR	BACKLOG AO/G3	BACKLOG IOD	MESSAGES DELIVERED LAST 1/4 HR	MESSAGES DELIVERED ANYTIME	MESSAGE UNITS COMPLETED AO/G3	COMPLETED IOD	REJECTED AO/G3	REJECTED IOD	INTERUPTED AO/G3	INTERUPTED IOD
1	0	0	2	8	7.0	7.0	1.0	0	2.0	0
2	3.0	0	2	8	13.0	11.0	0	0	0	2.0
3	0	2.0	3	12	15.0	14.0	0	0	0	3.0
4	0	3.0	2	3	5.0	6.0	0	0	0	1.0

Figure 8. Sample run summary from MANMODEL.
(Siegel, Wolf, and Leahy, 1977)

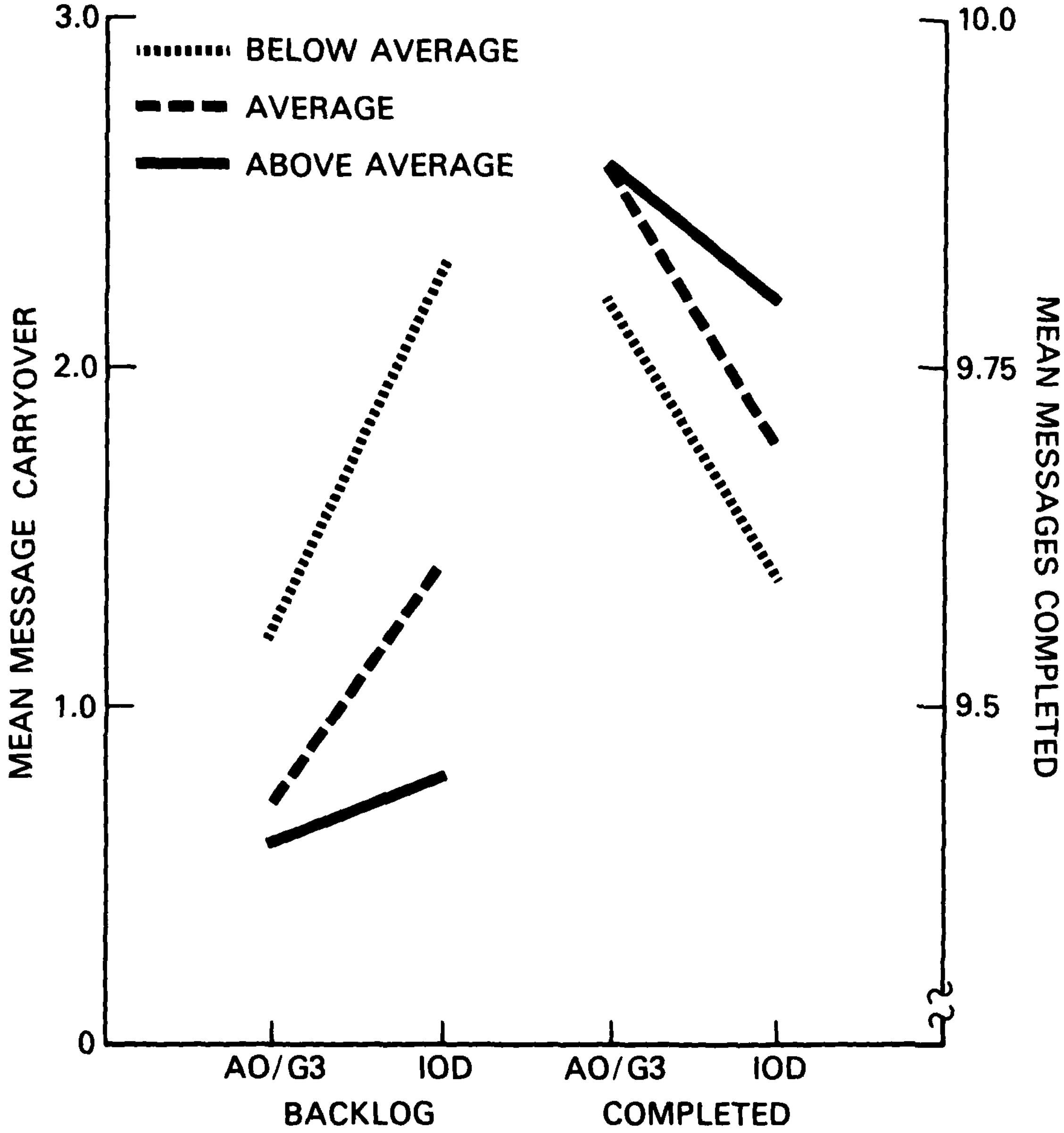


Figure 9. Sample sensitivity test performed on MANMODEL. Mean number of messages carried over and completed as a function of operator skill level. (Siegel, Wolf, & Leahy, 1977)

For the system designer, MANMODEL offers a low cost tool with which to explore a large variety of design alternatives. By way of illustration, consider a situation where a proposed system design produces ineffective performance during a simulated run. Examination of the simulation data might indicate that it is the system's responsiveness (as opposed to thoroughness, completeness, or accuracy) which is responsible for the poor performance. The average message handling time and the average queue time are both excessive. A continued examination of the simulation data might also show that personnel are busy a high percentage of the time. The system designer can now examine the remainder of the data in an effort to determine the probable cause of these events. For example, an inspection of the Error Run Summary might indicate that the system's error correction procedures are a drag on the system. To remedy this, the system designer might consider a variety of corrective measures such as: improved operator training (Gade et al., 1978); improving the input procedures (Fields et al., 1978; Sidorsky, 1974); modifying the procedures so as to reduce the number of undetected errors (Strub, 1975); or reducing the cognitive load (Nystrum & Gividen, 1978). Each of these candidate solutions may be simulated on MANMODEL and the anticipated performance benefits compared on the basis of overall system requirements and cost of implementation.

MANMODEL was initially developed for use on a large scale computer with batch processing. However, the program has since been modified to allow on-line manipulation of input parameters as well as control over program execution. Additional improvements and enhancements that have been made to MANMODEL include the simulation of the error correction process and the acceptance by MANMODEL of data provided by a prior simulation of the communication network (Leahy et al., 1979a, b). In the latter case, the human performance predictions made by MANMODEL are then used as input parameters for a simulation of a tactical operations system. A computer-experimenter-subject interactive mode has also been developed (Leahy, Lautman, Bearde, and Siegel (1977); Siegel, Wolf, Leahy, and Bearde (1977)). This permits the simulation to make use of actual, real-time data provided by a subject-operator who is interacting with the system. In this mode, subjects perform system tasks and their data are reduced and treated statistically for use in the simulation.

In summary, MANMODEL provides an evaluative vehicle for comparison of alternative system configurations, operational procedures, and personnel characteristics (e.g., training, aptitude, motivation). It also permits the system designer to identify and manipulate critical human factor parameters, to empirically investigate design alternatives, and to determine critical issues.

GENERAL DISCUSSION

Research on the data entry process has been responsible for refining the input procedures and improving the transform operation in battlefield automated systems. Of the seven experimental studies cited in this paper, the recommendations of three have already been implemented and the recommendations of two others are currently being considered. However, in spite of considerable progress, the basic parameters of the data entry process have not been fully defined or investigated. One reason for this shortcoming is the lack of compatibility in the message formats (stimuli), personnel and other factors used in the various experiments reported above. This lack of compatibility between experiments makes it difficult both to reconcile conflicting findings and to formulate a

total theory from the individual findings. Some of the factors which have been found to vary greatly from experiment to experiment, and which thus led to this situation, are listed below.

1. Measurement of input times--No apparent consensus has been reached as to how to measure data entry times. Some experiments report the time required to input an entire message while others report only the time required to perform discrete parts of the data entry. The time measures used are specific to the experimental objectives and depend upon task characteristics. They are not amenable to cross comparison or even to a chronometric approach of additive task times without caveats for cautious interpretation.

2. Stimulus set--Depending upon the message formats (e.g., to make a change in the data base vs. query the data base) and message type (e.g., "friendly" vs. "enemy" messages) used as stimuli in an experiment, different error rates will be observed. This makes it difficult to compare experiments that use different classes of stimuli.

3. Instruction set--Although this variable is difficult to assess because it is not reported in detail in all studies, it is obvious that some research (either implicitly or explicitly) emphasizes accuracy over speed while other research gives equivalent weights to the two. None of the experiments appear to emphasize speed over accuracy. The results of many of the experiments reported above may have been affected by the ability of operators to trade-off between speed and accuracy, giving emphasis to one or the other (Howell & Kriedler, 1963). On a related matter, Baker (1963) recommends the use of programmed-instruction techniques so as to eliminate "delivery of instructions" as a variable within an experiment and also to eliminate experimenter bias in the delivery of instructions.

4. Effect of practice on operator performance--Evidence indicates that the performance of data entry tasks shows improvement with practice over periods at least two years long (Klemmer & Lockhead, 1960, 1962a, 1962b). In addition, the actual mode of operation and the abilities used in entering data change with practice and with performance improvement (Fleishman, 1960, 1965; Leonard & Newman, 1964). Well skilled data entry operators use the redundancies in the input data to encode those data into "higher order units" which are then processed as wholes; on the other hand, unskilled operators use a character-by-character mode of entry (Seibel, 1972). For some research, the nature and extent of the practice and the training of the subjects was not specified. Thus, the data entry rates (especially error rates) that are reported may have been differentially influenced by the amount of practice provided to the operator subjects.

5. Variability of subject (operator) samples--The range of operator familiarity with and expertise in the operation of the TOS system was considerable in the different experiments--from officers working on TOS development and knowledgeable in G3 operations to enlisted personnel with low GT scores and no prior experience using TOS procedures. This variability may have contributed to the differences in error rates and data entry times.

6. The type of input device--Extensive reviews (Alden, Daniels & Kanarick, 1972; Seibel, 1972) have shown that error rates and data input times may vary as a function of the data input device. Although the standard "QWERTY" keyboard, usually employed in a CRT terminal, was used most often, other devices such as a keyboard without a CRT or handwritten messages were also used in some experiments.

A second shortcoming in the present research was the lack of focus on the basic distinction between the dynamic cognitive processes that are involved in a task (such as retrieving information from memory and using it to transform a message) versus the relatively mechanical aspects of a task. Fields et al. (1978) acknowledged this distinction, at least implicitly, when they noted that their "menu" format method yields fewer errors on an input task than does various typing methods. They attributed this to the possibility that fewer errors will occur because the use of menus places a smaller cognitive load on the user, as it requires the use of recognition memory rather than recall memory. Two ways by which errors can be made while translating information into computer readable forms are: (1) the problem of forming a correct concept of the information and (2) the problem of inputting properly formatted information based on a correct concept. Attributing errors to one of the two causes mentioned above becomes difficult when the experimental paradigm confounds cognitive processes with rote motor behavior. If the basic parameters which affect the cognitive versus motor aspects of the data entry process are delineated, differential weightings (e.g., as a function of task or input device) may be both experimentally and then operationally assigned to them. Isolating the cognitive versus motor aspects of the data entry task and assessing the variables which impact upon them is a potentially fruitful area of research.

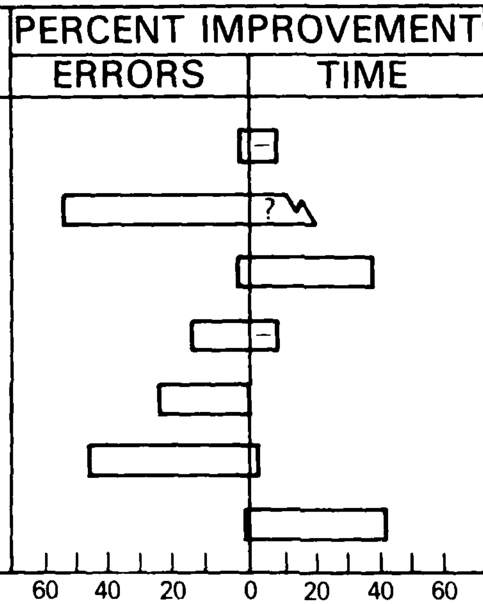
Other potential areas of research are the linguistics of user-computer communication, training methods, operator selection techniques and keyboard design. With regard to this last item, the current state of the art seems to accept the QWERTY keyboard as standard in spite of evidence to indicate that other keyboards may just be as, if not more effective for certain types of tasks. Research on the technical parameters of keyboards (Alden et al., 1972) and the characteristics of keyboard operators may lead to rapid improvement in the data entry process. Finally, research should consider the emerging technology for computer input and output of speech coupled with the apparent benefits of entering data at the source (i.e., observed on the battlefield).

SUMMARY AND CONCLUSIONS

A number of ARI research studies have investigated techniques for improving the TOS data entry process through procedural and hardware changes. Many of these studies report reductions in the time required to enter data and/or reductions in the error rate. The degree to which this research program has improved performance is shown in Figure 10. The more important findings and operational implications that can be derived from this program are listed below.

TOS DATA ENTRY PROCESS
RESEARCH HIGHLIGHTS

REF*	TASK	PERCENT IMPROVEMENT[a, b] (ERRORS / TIME)	COMPARISON
A	FORMAT SELECTION		TOS MENU VS JOB AID
B	MESSAGE ENTRY		TOS PAPER FORM VS ON-LINE, VERIFIED***
C	MESSAGE ENTRY		TOS STANDARD VS COMPUTER JOB AID**
D	MESSAGE ENTRY		STANDARD VS ADAPTIVE FEEDBACK**
E	MESSAGE ENTRY		TYPEWRITER VS MENU SELECTION***
F	MESSAGE CODES		TOS LL# VS LLLL FORMAT CODE***
G	DATA INPUT		TYPEWRITER VS 5 KEY ALPHA DOT



*REFERENCES:

A. BAKER ET AL (1969)
B. STRUB (1971)
C. STRUB (1975)
D. GADE ET AL (1979)
E. FIELDS ET AL (1978)
F. NYSTROM & GIVIDEN (1978)
G. SIDORSKY (1974)

a. PERCENT IMPROVMENT ADVANTAGE OF SECOND ITEM OVER FIRST ITEM (E.G., FOR REFERENCE A: JOB AID PRODUCED APPROXIMATELY 5% FEWER ERRORS THAN DID THE TOS MENU).

b. A MINUS SIGN WITHIN A BAR INDICATES THAT THE IMPOVEMENT WAS NEGATIVE (E.G., TIME TO PERFORM THE TASK INCREASED).

***IMPLEMENTED
**AWAITING DECISION MILESTONE

Figure 10. Summary of major ARI research dealing with the data entry process.

1. The number of different formats used in data entry should be reduced through possible consolidation. Previous TOS designs have contemplated using up to 500 different formats. Such a large number of choices makes it difficult for the operator to properly select the appropriate format. (This recommendation has been implemented.)

2. The transformation and input of the TOS message should be performed by a single operator and as a single operation. The intermediate step of completing a paper format as well as the role of an action officer are redundant, error contributing and should therefore be eliminated. (This recommendation has been implemented.)

3. Menu selection is the superior technique for data entry. However, one must still determine the most efficient form for setting up a menu. (This recommendation is being implemented.)

4. Message formats are best designated by the use of all-letter code as opposed to a mixed alpha-numeric code. (This recommendation has been implemented.)

5. Flexibility and cost efficiency in the design of data entry systems can be achieved through improved computerized modeling. MANMODEL represents a case in point. (This recommendation has been implemented.)

6. Response-sensitive training (where the training session automatically adjusts to changes in the operator's performance) is an effective method for reducing training time without sacrificing input accuracy. However, the decision on whether to implement such a training technique requires an analysis of its cost. (This recommendation is under consideration.)

7. The Alpha-dot Keyboard provides an alternative data entry device for use by frontline observers on the battlefield.

8. Approximately 80% of all data entry errors are not detectable by computerized error detecting routines. Better human factors design and improved training techniques are required on battlefield automated systems. Improved error taxonomies are useful for this purpose.

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